ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
SUBSCRIPTION PRICE, $3.00 PER YEAR

JOURNAL OF AGRICULTURAL RESEARCH

DEPARTMENT OF AGRICULTURE

VOL. VI WASHINGTON, D. C., MAY 22, 1916 No. 8

HYPODERMA DEFORMANS, AN UNDESCRIBED NEEDLE FUNGUS OF THE WESTERN YELLOW PINE

By JAMES R. WEIR,

Forest Pathologist, Office of Investigations in Forest Pathology, Bureau of Plant Industry

INTRODUCTION

In the summer of 1913 the writer's attention was drawn to what appeared to be a very serious needle disease of the western yellow pine (*Pinus ponderosa* Laws.) in parts of Idaho, Washington, and Montana. That the disease has become more prevalent is shown by the receipt at the Laboratory of Forest Pathology at Missoula, Mont., of many collections of the fungus from localities where it was not before known to exist. These collections represent material from trees of all ages and show the youngest needles as badly diseased as the oldest ones. The first suspicion that the fungus might be of some economic importance arose through the discovery of a serious infection of young reproduction over a large area in the Whitman National Forest, Oregon. From the fact that the fungus causes a conspicuous hypertrophy by the extension of its mycelium into the tissues of the twigs and also through the destruction of the youngest needles, consequently causing in some localities much damage in the forest, it seems desirable to make known its characteristics.

TECHNICAL DESCRIPTION OF THE FUNGUS

Since the fungus does not agree with any known member of its genus, it is described as new.

Hypoderma deformans, n. sp.

Apothecia black, shiny, averaging 10 mm. in length and 1 mm. in breadth; may extend as a black line the entire length of the sheath side of the needle or be broken up into a series of shorter apothecia, usually arranged along the middle line of the needle, but may appear at either side and be very rarely confluent with the more medially arranged apothecia; opening with a longitudinal medial split. Asci fusiform (26) 26.1 to 43.5μ by 159.5 to 207.2μ (27.3 to 29.0μ by 171.5 to 186.4μ). Spores parallel or obliquely arranged in the ascus, very generally slightly curved, uniform breadth, rod-shaped, ends blunt, 1-septate when mature, septum very conspicuous, cells often apparently separated, pale olive, almost hyalin, eight to an ascus (40) 6.2 to

9.7μ by 90.67 to 131.37μ (7.4 to 8.7μ by 108.9 to 117.6μ); paraphyses numerous, filamentous, swollen at the ends or recurved. Spermogonia intermixed averaging 5 mm. in length; spermatia elongated, straight, sometimes slightly curved, hyalin, continuous, averaging 1 by 8μ.

Type locality: Sumpter, Oreg., Whitman National Forest.

Habitat: Living needles of *Pinus ponderosa.*

Type material deposited in the Office of Investigations in Forest Pathology, Bureau of Plant Industry, Washington, D. C., and in the collections for study in the Laboratory of Forest Pathology in the same office, at Missoula, Mont.

GENERAL BIOLOGY OF THE FUNGUS

The apothecia of the fungus are the most conspicuous of any of the group on pines in the West (fig. 1). From new infections of the previous year fully mature apothecia with well-developed spores (fig. 2) may be collected in early spring. From this time on the longitudinal split on the medial line of the apothecium is plainly visible, and may remain open or closed, depending on the humidity of the atmosphere.

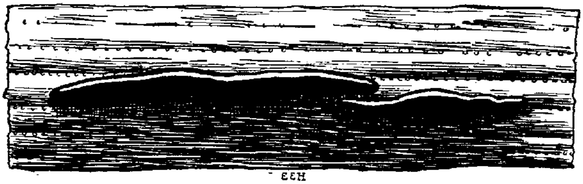


FIG. 1.—A side view of two apothecia of *Hypoderma deformans* on needles of *Pinus ponderosa*, showing the longitudinal medial split.

The splitting of the epidermis on the needle directly on the medial line of the apothecium is a characteristic shown by nearly all of the Hysteriaceae and in a few cases seems to be governed by a particular structure of the overlying layers of the apothecium. Thus, Von Tubeuf [1] points out that the pseudoparenchymous covering of the apothecium of *Lophodermium pinastri* (Schrad.) instead of being one continuous homogeneous tissue is made up of two parts which come together on the middle line of the fruiting body. The edges of the two parts interlock by a series of short papillæ. It is on the line of these papillæ, when the pressure within the apothecium becomes sufficient, that the epidermis of the needle ruptures. In *Hypoderma deformans* the rupture of the apothecium is apparently made easier by the coalescence of filamentous elements springing from the floor of the apothecium and meeting with the darker tissues of the apothecial covering above. Owing to a differentiation of the covering of the apothecium at the point of union a line of rupture is formed.

[1] Tubeuf, Carl von. Studien über die Schüttekrankheit der Kiefer. *In* Arb. Biol. Abt. Land- u. Forstw. K. Gsndhtsamt., Bd. 2, Heft 1, p. 22, 1901.

Pressure within the apothecium on approaching maturity, together with the elongation of the central elements, causes the rupture to occur on this line. After initiating the line of rupture, the filaments disappear and no sign of their presence exists when the spores are mature. In all material so far examined this mechanism is a constant characteristic. Where two apothecia are formed side by side, the filamentous structures are in marked contrast to the division line between the two apothecia as formed by the union of the darker colored elements of the apothecial covering. Von Tubeuf found in *Hypoderma strobicola* Tub. (*Lopho-*

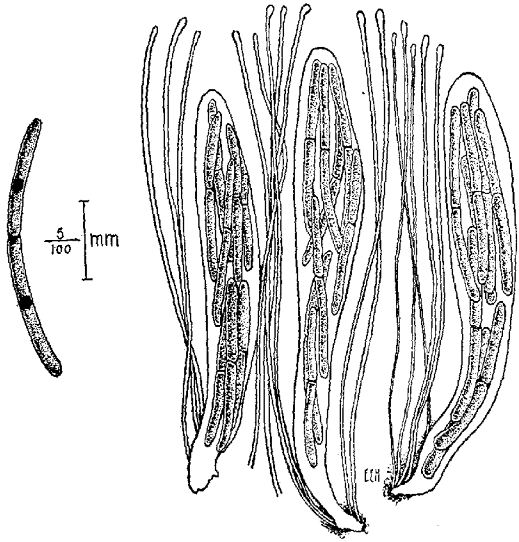


FIG. 2.—Asci, spores, and paraphyses of *Hypoderma deformans*.

dermium brachysporum Rostr.) the same structure which he describes for *Lophodermium pinastri* (Schrad.), but no such structures were found in *H. deformans*.

Apothecia with mature spores (fig. 3) may be found at any season of the year. This is due to the fact that the spores do not ripen or are not all freed simultaneously when the split first appears in the apothecium. The process of spore liberation is observed to extend over a long period of time. A year may elapse before the apothecia have entirely liberated their spores. During periods of drought the medial slit in the apothecial covering remains closed, only opening on the return of abundant

moisture. The hygroscopic movements of the lips of the apothecium furnish the method by which the spores are forced or ejected from the asci. As Von Tubeuf[1] has pointed out in the case of *Lophodermium pinastri*, the spores are shot out from the mature asci under proper conditions of moisture. This fact is easily demonstrated by inclosing short pieces of previously moistened needles bearing mature apothecia in the cavities of plate-glass culture slides. A microscopic study of such preparations shows that the spores are shot out from the asci a distance of from 1 to 2 mm., showing as a plainly visible deposit on the floor and cover of the cavity. The depth of the cavity in the slides used was 2 mm.

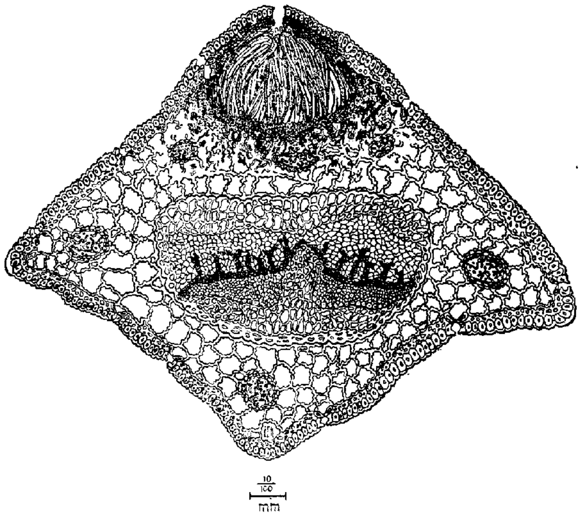


FIG. 3.—Cross section of an apothecium of *Hypoderma deformans* on a needle of *Pinus ponderosa*, showing mature asci with spores, the point of first rupture, and the tissues of the leaf most seriously affected by the mycelium of the fungus.

Occasionally an entire ascus was ejected and lay among the spores. In most cases, the asci remained attached and the spores were expelled through their terminal pores (fig. 4). Only the fully developed spores were cast out of the apothecia. After the material had remained in the slides a day and a half, during which time the spores were being ejected, the cover glass of a slide was removed and the material allowed to dry by exposure to the air of the laboratory for 30 days. The material was washed and replaced in the cavity in the slide. Within three hours spores from the same apothecia were expelled in considerable numbers but not so profusely as before. The process was repeated with shorter

[1] Tubeuf, Carl von. Op. cit., p. 24-25.

periods of drying till on the fourth trial no spores were liberated. An examination of the apothecia showed the asci to be entirely empty. This experiment not only demonstrates that the fungus has the ability to resist protracted periods of dryness but that the period of spore liberation may be much protracted, depending upon the atmospheric humidity. During wet weather apothecia expel their spores in visible quantity when a sharp blow is given the branch bearing infected needles.

Considering the long periods of drought in most yellow-pine regions, it is safe to assume that an apothecium ripening in early spring may first become emptied of its spores during the ensuing winter or even later. This is important for the propagation of the fungus, since new infections are possible from the time the first needles of the season appear till the close of the growing season.

In order to determine the viability of the spores expelled from apothecia after long dryness, a 2 per cent sugar solution was introduced into the cavity of one of the slides containing apothecia which had lain dry in the laboratory for two months and the slide placed in the thermostat at 35° C. On the fourth day spores germinated readily. The germ tubes appeared more frequently from the ends of the spores. A slight addition of an extract of pine needles to the sugar solution promoted germination.

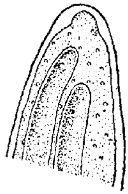


FIG. 4.—The upper portion of a young ascus of *Hypoderma deformans*, showing the formation of the pore at the tip through which the spores are expelled.

It was noticed that in collections of the fungus made shortly after warm summer rains the asci are frequently empty as compared with asci of mature apothecia collected in the colder spring months. This, it seems, may not be entirely due to a longer period of spore liberation but also to the higher temperature of the summer months. Von Tubeuf found that increasing temperature promoted spore liberation in *Lophodermium pinastri* and it is found to be true in experiments with the yellow-pine fungus. During the winter, moistened apothecia from dry material were mounted in two culture slides; one was placed outside the laboratory during a period when the thermometer registered about 40° F. and the other was kept in the laboratory air of about 80° F. At the end of four hours a microscopical examination showed that a large number of spores had been ejected from the apothecia in the slide kept in the laboratory but none from the other slide. When the slide from the outside was allowed to stand for a while in the warm air of the laboratory, spores were liberated in quantity.

Although spores from various needle fungi are undoubtedly more readily liberated during warm rains of the summer months, the frequent drying of the foliage of the trees is probably not favorable for infection. It is frequently observed, and as often reported, that needle fungi become more active during the cool, protracted rainy periods of early spring and late fall. No extensive data are at hand regarding the resistance of

expelled spores to drought and direct light; still, the fact that dry herbarium material a year old was found to furnish viable spores shows that spores may exhibit considerable resistance to dry air when free from the apothecium.

PARASITISM OF HYPODERMA DEFORMANS

An attempt to grow the fungus on culture media failed. The spores in every case germinated and in some cases produced an abundant white mycelium, but in the course of six months, after frequent transfers, the mycelium turned a light yellow and died. A somewhat better result was obtained by adding to the culture medium a strong extract made from yellow-pine needles in water, but at the end of eight months the mycelium died.

A quantity of needles bearing apothecia with mature spores were collected in the spring of 1914 near Missoula, Mont., and taken to the field station in the Priest River Valley, Idaho, for experiments on parasitism. The fungus has not been found in this region. The needles were thoroughly washed in distilled water and the apothecia allowed to expel their spores in small sterilized flasks. Needles and spores were shaken up in water to which a 1 per cent sugar solution was added. The mixture was allowed to stand one day and then thoroughly sprayed over four 3-year-old yellow-pine seedlings having young tender shoots with needles. The inoculated seedlings were immediately inclosed in tough, transparent oiled paper bags and protected from injury. A second experiment was initiated by binding infected needles on healthy 3-year-old seedlings. In the part of the Priest River Valley where these experiments were performed the yellow pine is not common, being only sparingly represented in a mixture of white pine, grand fir, spruce, hemlock, and Douglas fir. The experiments were made on May 20. In September the last-formed needles of the inoculated seedlings were turning reddish brown in spots, mostly at the tips. In the following spring, May to June, the needles which showed infection in the fall and which had become wholly brown developed the characteristic long, shiny black apothecia with mature spores (Pl. XXXII, fig. 1). Only the needles formed during the previous year were infected. Four control plants, also covered with bags, were entirely free from the disease. The needles of the seedlings on which infected needles were bound showed a much more general infection of the last-formed needles than those by the former described method. In these experiments every needle produced in 1914 was infected. Those of previous years remained healthy. This indicates that old needles are not attacked and that the young needles may remain attacked indefinitely after infection. All the infected needles did not produce mature apothecia. Those merely turning brown were filled with the mycelium of the fungus. The experiment at this point was discontinued. In all probability, given time enough, the brown-infected needles would have produced apothecia.

It has been noticed repeatedly in nature that there is great irregularity in the time between the first browning of the needles at their tips or at other points along the needles and the appearance of the mature apothecia. In a few cases the cycle of development from the first appearance of the brown color at the tips of the needles to mature apothecia has been observed to take place within the same calendar year, or from April and May to November. More often infected needles first showed mature spores in the spring of the following year. It was observed in a few cases that the needles may lie on the ground through the following winter before the apothecia rupture. Brown needles collected in August from infected trees and placed in damp moss in the field in a number of cases developed apothecia before January, maturing in May and June. The apothecia, as previously indicated, may contain asci in various stages of development, so that mature spores are being produced throughout the year. Investigation has shown, however, the greatest number of spores are expelled during the spring rainy season, May and early June, coinciding with the greatest vegetative period of the host. In no instance, either in the field or in artificial inoculation, were the infected needles of young trees or seedlings not previously attacked by the fungus killed before they had attained their normal size. In September or October, such needles will have assumed a more or less uniform reddish brown color. Mostly remaining upon the tree, they may first produce the signs of the apothecia during the late fall and mature the spores in the following spring. At the time the foregoing experiments were in progress small bundles of infected needles bearing fertile apothecia were bound with similar quantities of needles which had died from a normal cause. These were placed in moss during May, 1914. On examination in May of the following year the needles which had died from a normal cause showed no signs of the fungus; nor have they done so since that date. This apparently demonstrates the inability of the fungus to act as a saprophyte.

The foregoing observations and experiments apparently prove the parasitism of the fungus. This is further substantiated by the observed evidences that young seedlings in the field succumb to the ravages of the fungus. Furthermore, it is indicated that the period of greatest infection is during the growing season and only the needles of the season are to any extent susceptible to attack.

The fungus has not yet appeared in the forest nursery, but it may be regarded as a possible nursery disease.

PATHOLOGICAL EFFECTS OF THE FUNGUS ON THE BRANCHES OF THE HOST

A very peculiar and at the same time interesting phenomenon caused by the growth of the mycelium of the fungus in the shoot is the formation of spherical-shaped witches'-brooms on trees mostly past the seedling stage. These (Pl. XXXII, fig. 2) brooms in old trees often assume large proportions. A single witches' broom may weigh as high

as 100 pounds and measure 5 or 6 feet in diameter. The branch supporting it will hang vertically, the broom swaying in the wind like a great bag (Pl. XXXII, fig. 3). The average size of the brooms is about 2 feet in diameter. Although a few isolated cases had been noted on the seeming association of this needle fungus with these compact brooms, it was not until the field season of 1913 that this association was found to be of common occurrence. This was all the more interesting from the fact that the cause of these formations has been a standing question with all who have seen them. In some cases they have been attributed to the yellow-pine mistletoe, *Razoumofskya campylopoda* (Engelm.) Piper, an error, however, not likely to be made by anyone familiar with the type of broom caused by this mistletoe.

The distribution of the brooms is quite general through the range of the yellow pine in the Northwest. They are particularly abundant in the vicinity of the great lakes of Idaho and in the dry valleys of southern and western Montana. Climatic variation does not seem to influence their distribution.

In order to determine the cause and nature of the formation of these brooms and the relation, if any, between them and the fungus common on their needles, the subject has been under investigation in the field and laboratory. A number of interesting observations have been recorded.

The disease caused by *H. deformans* primarily affects the needles. In young pines the disease occurs quite generally at first, unaccompanied by any kind of hypertrophy of the shoots. Later the repeated destruction of the last-formed and older needles initiates a swelling of that portion of the branch. Sometimes the entire shoot succumbs to the attack in seedlings of tender years, especially the weaker individuals, caused, no doubt, by the rapid drying out of the shoot. In growths of 7 to 10 years the fungus confined itself to the needles of the season, with the result that on the infection of these a second crop sometimes appears about the terminal bud, which may or may not become infected but may remain in a stunted, deformed condition. They help, however, to maintain the shoot in a living condition. In a far greater measure than in any other member of the order the mycelium of *H. deformans* penetrates the leaf sheath and eventually perennates in the tissues of the shoot, causing a marked enlargement of the parts infected. The fungus, however, fruits only on the needles.

An additional result of the infection of the terminal shoots and the continued production of food materials by the older, uninfected needles is the stimulation of all lateral and adventitious buds either between the primary terminal buds or at the last two or three nodes. Eventually, the food materials are more and more diverted from the main shoot, resulting in a gnarled and curved bunch of short branches. Young trees

4 to 8 years old when uniformly infected are frequently observed with the terminal portions of every principal branch in the process of "brooming." The fact that the fungus sometimes occurs without the least sign of a hypertrophy of the branch does not indicate that it is not capable of producing such physiological and morphological changes. The fact remains that on all young growth almost always the twigs bearing the infected needles are abnormally swollen or branched. The fungus has not been found by the writer on mistletoe brooms or on any form of broom caused by insect or other animal injury. On large and mature trees *H. deformans* very rarely occurs on any part of the tree except the needles of these brooms. These abnormalities are scattered promiscuously over the tree, but principally on the lower branches. This indicates the nature of an infection. The more recent infections on old trees are usually distributed or isolated on particular branches. Serious injury seldom results from the growth of the brooms on more mature growth. Very rarely may the brooms become so heavy as to split-off the supporting branch.

As the result of an examination of the witches' brooms on yellow pine in the Bitter Root and Missoula River valleys, Montana, and the Coeur d'Alene region of Idaho, with respect to the presence of *H. deformans* on the brooms and the number, position, and distribution of the brooms on the tree, the following data were obtained:

On 107 trees examined, the average number of witches' brooms per tree was 3.2. These brooms generally appeared on the lower part of the crown on the side facing the prevailing winds. The average number of brooms per tree bearing needles showing apothecia of *H. deformans* was also 3.2.

These figures support the view that the peculiar brooms so common on yellow pine are the result of fungus infection and that the fungus responsible is *H. deformans*.

In the parts of northern Washington, Montana, and Idaho so far visited, *H. deformans* has not been found to attack the yellow-pine reproduction in as great a degree as in regions farther to the west and south. This is probably due to a greater mixture of species. The fungus is not able to spread with the same rapidity as in the more typical yellow-pine stands. The infected young growth usually continues alive indefinitely, and deformed branches appear, eventually resulting in an entire retardation of growth, and finally die. This process may require several seasons, but the infected pines never attain a very large size. Such deformed trees usually are attacked by bark beetles, such attacks hastening their decline.

In parts of Oregon in the yellow-pine belt the fungus was found to be very destructive. During an investigation of the larch mistletoe (*Razoumofskya laricis* Piper) in the vicinity of Sumpter, Oreg., the

yellow-pine reproduction, especially on south slopes under mature cover, was observed to be turning brown and in many cases dying. On examination the needles of these seedlings showed that they were infected with *H. deformans*. This is a grazing region, and the forest has been continuously grazed by large bands of sheep for many years. The stems of the young pines in numerous cases bore near their bases one or more wounds of a shape and nature indicating that they were produced by the treading of grazing animals. Since little information is at hand on the effects on forest production of wounding by grazing animals, it seemed worth while to make a detailed study of the case so far as time would allow, with the double object of determining which injury—viz, the needle fungus or the wounding—was responsible for the sickly condition of the young pines. It must be remembered, however, that the seedlings were growing under the canopy of a mature yellow-pine stand; consequently they were not growing rapidly in height. Four one-tenth-acre plots were laid off on representative south slope sites and every seedling on the plots carefully pulled up and bound in bundles. These bundles were sent to the laboratory and afterwards carefully diagnosed. The normal condition of root system and crown and general vigor of seedlings were judged from a knowledge of normal young pines of the same age, free from disease and wounds, growing in the same regions and under the same slope conditions. The results of this study were embodied in a preliminary table from which Table I was condensed as being more readily undestandable.

TABLE I.—*Number of seedlings on 4 one-tenth-acre plots, average age and height, condition of infection with Hypoderma deformans, present condition of wounding and root system, south-slope type*

Condition of seedlings.	Number of seedlings on 4 one-tenth-acre plots.	Average age.	Average height.	Vigor and general appearance of seedlings.
		Years.	*Feet.*	
Seedlings neither wounded nor infected.	40	10.7	2.8	Healthy green color, vigorous, normal, well developed root system.
Seedlings infected with *Hypoderma deformans* but not wounded.	67	13.0	1.3	Few green needles, most all badly infected and either dead or dying; twigs twisted or broomed; poorly developed root system; general picture of a starving condition.
Seedlings both wounded and infected.	127	12.1	1.4	Do.
Seedlings wounded but not infected.	49	12.8	2.14	Wounds mostly healed. Time required to heal, 1 to 4 years. Seedlings normal. Wounding apparently not affecting growth. Root system normal.

DISTRIBUTION OF HYPODERMA DEFORMANS

The disease of yellow-pine needles caused by *H. deformans* is widely distributed throughout the northwestern part of the United States and western Canada. Its distribution in other parts of the West is not known, although the fungus has undoubtedly been collected

by other observers.[1] The writer has observed and collected *H. deformans* in the National Forests of the Northwest as follows: Sioux, Helena, Deerlodge, Jefferson, Missoula, Coeur d'Alene, St. Joe, Clearwater, Selway, Bitterroot, Pend Oreille, Kaniksu, Nez Perce, Lolo, Cabinet, Flathead, Kootenai, and Whitman. The late J. F. Pernot, forest examiner, supplied specimens from the Deschutes, Wallowa, Malheur, Crater, Colville, and Wenatchee National Forests. Along the Thompson River in British Columbia the fungus was occasionally found by the writer in the summer of 1913.

CONCLUSIONS AND RECOMMENDATIONS

A very conspicuous disease on yellow-pine needles in many parts of the Northwest, the cause of which has for several seasons remained unknown, is found to be caused by a fungus which is described as a new species under the name "*Hypoderma deformans*."

H. deformans is a true parasite and attacks the foliage of all age classes; and in some of the more exposed sites of the typical yellow-pine belt of Montana, Oregon, Washington, and Idaho, young seedlings at first suffer great suppression and are finally killed.

The first sign of infection of the needles is usually a slight browning of the tips; or in the regions of heavy infection the entire needle may gradually assume a straw-yellow color, deepening to a brown on the first appearance of the apothecia.

Because of the destruction of the youngest needles and the penetration of the mycelium of the fungus in the tissues of the stems of the host, the terminal shoots do not attain their proper development, but become stunted and deformed, eventually producing a witches' broom. These witches' brooms on young yellow-pine saplings or older trees are often very conspicuous and often occur in such numbers as to make either an individual tree or an entire stand look very ragged and unsightly.

Up to the present time the disease has not been found in the forest nursery, but it may be regarded as a possible nursery disease. Since the vegetative mycelium of the fungus may hibernate in the shoots of seedlings after the infected needles have fallen, the fungus may make its appearance in the forest nursery and may be unknowingly transferred to the planting areas.

The presence of the fungus on mature forest trees is very readily recognized by the foliage browning up in patches or by the formation of brooms. Since the fungus does not affect the merchantability of the tree, except by influencing the increment in cases of very severe infection, all trees of the regulation diameter classes should be marked for

[1] Meinecke describes a very destructive needle fungus, under the name "Hypoderma," on yellow and Jeffrey pines, which apparently is the same fungus as the one described in these pages. (Meinecke, E. P. M. Forest Tree Diseases Common in California and Nevada, p. 54. Washington, 1914. Pub. by U. S. Dept. Agr. Forest Serv.)

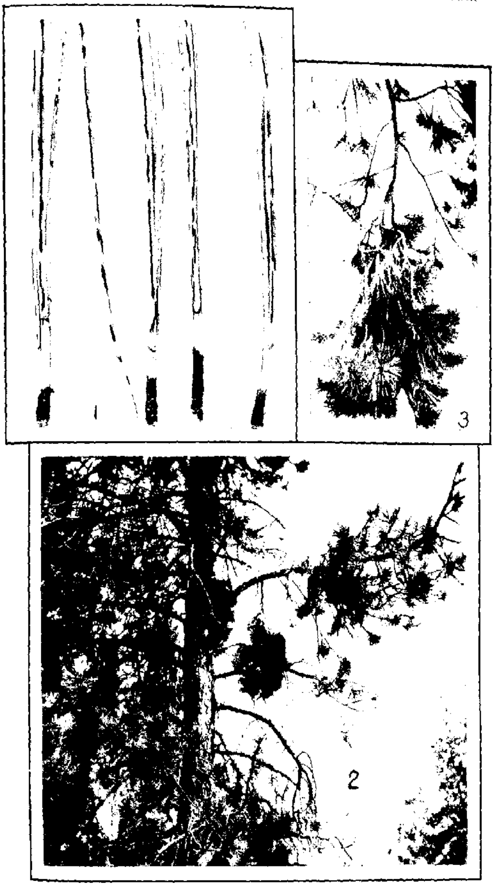
cutting. The brooms never produce cones and the normal parts of the supporting branch are usually sterile. The branches bearing patches of infected needles or brooms should be piled and burned as soon as possible. This may be done in the course of the regular brush-piling operations. If young trees below the regulation cutting diameter are so badly "broomed" that in the opinion of the forest officer the increment of the tree will be seriously impaired, and whenever the cost is not prohibitive, such trees should be lopped and immediately burned. The chief reason for such procedure is to protect the reproduction from infection, thus insuring a healthier forest in the future.

PLATE XXXII

Fig. 1.—Needles of *Pinus ponderosa* infected with *Hypoderma deformans*, showing the apothecia. Natural size.

Fig. 2.—Branches of *Pinus ponderosa* deformed and broomed by *Hypoderma deformans*.

Fig. 3.—A branch of *Pinus ponderosa*, showing how it will hang vertically when supporting a large broom caused by *Hypoderma deformans*.


3
2

ORNIX GEMINATELLA, THE UNSPOTTED TENTIFORM LEAF MINER OF APPLE

By L. HASEMAN,[1]

Entomologist, Missouri Agricultural Experiment Station

INTRODUCTION

The small, unspotted tentiform leaf miner (*Ornix geminatella* Pack.) has been extremely abundant in Missouri in recent years and has attracted the attention of fruit growers throughout the State. It has confined itself largely to bearing apple (*Malus sylvestris*) orchards, though considerable injury has been done to apple foliage in nurseries. Fortunately, it is most abundant in the late summer and early fall, so that its work is of less importance to the trees. As with many insect pests, it seems to run in cycles. It was most abundant during the summers of 1911 and 1912, reaching a climax in 1912. Since 1912 it has attracted little attention.

It confines its work to the leaves and spends most of its larval life inside the leaf as a true miner. The caterpillar therefore is small, though the characteristic elevated, or tentiform, dead patches which it produces on the leaves are quite noticeable. In some cases as many as 15 mines have been found on a single large apple leaf (Pl. XXXIII, fig. 14, 15). The pest was so abundant and so widely distributed throughout the State that a careful study of its life history, habits, and control was undertaken.

HISTORY OF THE PEST

The moth was first described and figured by Packard (7, p. 353)[2] in 1869 as *Lithocolletes geminatella*. The description and figures are incomplete and not entirely accurate, owing perhaps to incomplete observations. Since its first discovery it has been collected by various workers and was redescribed by Chambers (2) as *L. prunivorella*. Other closely related micros have been mistaken for it, and some careful observers have given very inaccurate descriptions of its work and habits.

DISTRIBUTION OF THE LEAF MINER

Packard reported it as being abundant in New England on pear and apple; Lowe (6) reported it as being very abundant on apple in New

[1] The writer wishes to acknowledge his indebtedness to the late Miss Mary E. Murtfeldt, of Kirkwood, Mo., to Miss Annette F. Braun, of Cincinnati, Ohio, and to Mr. August Busch, of the Smithsonian Institution, Washington, D. C., for assisting with the naming of the leaf miner; and to Dr. L. O. Howard, Chief of the Bureau of Entomology, and to Mr. A. A. Girault, of the same Bureau, for the determination of the parasites. He is also especially indebted to Prof. C. R. Crosby, of Cornell University, for helpful suggestions and for assistance in naming the leaf miner and the parasites.

[2] Reference is made by number to "Literature cited," p. 295.

York, and Brunn (1) reported it from Ithaca, N. Y. Forbes (4, p. 57) reported it from Illinois, New York, Colorado, Kentucky, Michigan, and Massachusetts; and Jarvis (5, p. 49) reported it as being common in Connecticut. Dietz (3) reported it from the Middle and Northern States of the Atlantic slope, though he confused species. In a recent attempt to determine its present distribution the writer has been able to get definite records from but one additional State, Ohio. It is probable that it is found from the Atlantic States to Colorado, but being so small and inconspicuous, except when abundant, fruit growers and entomologists have overlooked the insect and its work.

LIFE HISTORY OF THE MINER

The writer has not been able to find any report of the complete life history of the pest. Such records as are available deal with the insect and its development and work in the summer or more often for a short period in the late fall. In some cases very careful data have been recorded, but many of the records and descriptions are decidedly at fault. The following records for the insect in Missouri have been collected since the summer of 1911 and include new data on the life history, development, and habits of the pest.

EGG

The egg is extremely small, slightly oblong, varying from 0.254 to 0.4 mm. in length and from 0.18 to 0.29 mm. in breadth, only slightly elevated and firmly cemented invariably to the lower surface of the leaf. (Pl. XXXIII, fig. 3.) It is so small that it can scarcely be detected with a hand lens, and the writer has failed to find the unhatched eggs on foliage, though many have been collected and studied soon after hatching, when the young caterpillar had just begun to start its mine. The adults have refused to lay eggs in captivity in small vials; therefore, these records are for the freshly hatched eggs.

THE LARVA

On hatching, the larva is footless and resembles a microscopic flat-headed borer. It always seems to break through the part of the shell which is cemented to the leaf and enters the tissue of the leaf at once. The freshly hatched caterpillar is less than a millimeter in length. It grows rapidly and when mature is about 6 mm. in length. In its development it passes through four distinct larval stages. There is considerable variation in size, but the following measurements are the average of many specimens.

In the first stage the caterpillar is pale, with a slight yellowish tinge to the head. The head and thorax are enlarged and it is footless. It molts when it is yet less than 2 mm. in length, and the head capsule is about 0.18 mm. in breadth. (Pl. XXXIII, fig. 4.)

In the second stage the body is pale, the head becomes brownish, a black blotch begins to appear on the first thoracic segment, legs are still absent, the head capsule is about 0.27 mm. broad, and the caterpillar is about 2.2 mm. long. (Pl. XXXIII, fig. 5, 6.)

In the third stage the body is at first pale, but darkens with age; the thoracic and abdominal legs appear; the thoracic blotch breaks up into four irregular spots; the head becomes darker and is about 0.35 mm. in breadth, while the caterpillar is about 4.5 mm. in length. (Pl. XXXIII, fig. 7.)

In the fourth stage the caterpillar is about 6 mm. long and the head capsule is 0.49 mm. broad; the body takes on an olive-gray color, sharply contrasting with the conspicuous white tubercles; the head becomes darker, and along its hind margin appears a row of four small black spots which parallel the similar row of larger spots on the first thoracic segment. (Pl. XXXIII, fig. 8, 9.)

THE MINE

While the caterpillar is changing from a pale, flat, footless, microscopic caterpillar to a conspicuously marked, cylindrical, active one, its mine also undergoes distinct changes. At first the mine is serpentine in form; but after it is from 4 to 8 mm. in length and is usually curved upon itself, the caterpillar begins to transform it into a blotch mine. (Pl. XXXIII, fig. 13.) The blotch mine begins by the third day, and about that time the caterpillar changes to the second stage. At first the blotch appears only on the lower side of the leaf. The lower layer of the leaf is separated from the upper by the flat caterpillar, and soon the severed lower layer dies and turns brown. The mine remains in the blotch stage about four or five days, and during that time the caterpillar changes to the third stage. When complete, the blotch is from 1 to 2 cm. long and usually occupies all the space between two of the main lateral veins of a leaf. On preparing to produce the tentiform mine, the caterpillar spins silk threads on the floor of the mine, which causes the lower dead layer of the leaf to become folded lengthwise of the mine. These threads, with others spun later under the roof of the mine, cause the upward projection of the mine. Just about this time the caterpillar changes to the fourth stage and begins to feed on the chlorophyll cells, and this in time gives the unspotted effect when a clear net work of veins appears. During the latter part of June it was found that in from a week to 10 days after the young caterpillar begins to feed, the mine is changed from the serpentine through the blotch to the tentiform type. The majority of the feeding and growth occurs in the third and fourth stages, and after the tentiform mine is made it requires from four to seven days to eat out all the chlorophyll cells and give it the completed, unspotted, tentiform appearance. The larval life in the mine is therefore about two weeks. The caterpillar leaves

the mine through a small hole in the floor of the mine and after crawling about for a varying length of time prepares to make a cocoon in which to pupate.

COCOON

The cocoon is almost invariably made on the upper surface along the edge of the leaf or at its very tip. On preparing to make the cocoon the caterpillar first rasps off and eats a patch of the surface layer of cells along the edge of the leaf, about 4 mm. wide and twice that in length. This causes a withering of the tissue and a slight folding over of the edge of the leaf. Then begins the work of spinning silk. First a loose layer of silk threads is spun from a line about 2 mm. from the edge of the leaf to the inner edge of the patch rasped off. Then follows a second layer of threads which are drawn very tight as they are placed. The anterior two-thirds of the body of the caterpillar enters into this work with great energy and force. The caterpillar's silk press must be a strong one. This layer only slightly draws up the edge of the leaf, but after transversed bands are used to tie the tight threads in bundles the edge of the leaf is perceptibly folded. At this time a second layer of foundation threads are spun underneath and then the work of drawing tight threads is continued along one end of the future cocoon. In half an hour the leaf edge is half drawn over and the hardest part of the work is completed. After the edge is tied down tightly the inclosed space is thoroughly lined with snow-white silk, so that a very dense semicircular cocoon 8 mm. long is formed. (Pl. XXXIII, fig. 12.)

PUPA

The mature caterpillar pupates soon after the cocoon is completed. The pupa is about 4 mm. long, exclusive of the antennal sheaths which project fully a millimeter beyond the tip of the body (Pl. XXXIII, fig. 10, 11). The pupa darkens with age, becoming dark brown on the dorsum and yellowish brown on the venter. The leg, wing, and antennal sheaths are all distinct. The pupal period varies from a few days to a week in midsummer.

MOTH

The newly-emerged adult on assuming its full splendor is truly a beautiful creature when viewed through a microscope. When left undisturbed it will stand perfectly still for hours, with the head elevated and the tip of the wings and abdomen lightly touching the surface on which it rests (Pl. XXXIII, fig. 2). This is its characteristic pose, and it holds it so perfectly that prolonged exposures for enlargements can safely be made. While in this pose the light flashes from every properly arranged scale as from polished metal, and one who is only familiar with the appearance of museum specimens can hardly appreciate the peacock-like splendor of this seemingly proud little creature.

Brunn's (1) description of the adult is very good. To the unaided eye the moth is slate-gray with a slight tinge of brown, being lighter in ruffled specimens. The ventral surface of the body is lighter in color. The markings on the front two pairs of legs are similar. The tarsal segments are white, tipped with black; the tibia and femur vary from dark brown to black with lighter patches; the coxæ are mottled with white and dark scales. The tarsal segments of the hind legs are brownish with white basal bands, while the tibia, femur, and coxa are much lighter, being nearly the same color as the lower surface of the abdomen. The palpi are prominent and banded with white and dark scales. The brownish proboscis is unusually long, reaching to beyond the base of the abdomen which, though it has not been observed to do so, would lead one to conclude that the moth feeds. The antennæ are brownish in color and distinctly annulate with whitish. In life they are closely pressed along the sides of the body and reach to beyond the tip of the abdomen and wings.

The surface of the forewings is beautifully mottled with light and dark scales. The light scales are arranged in eight or nine more or less distinct transverse bands. In museum specimens it is difficult to distinguish these bands. Near the tip of the forewings in fresh specimens, is a distinct black patch of scales bordered without by three alternating, narrow, white and black curving bands, giving to the tip of the wings a distinct peacock spot. On the hinder margin of the front wings the black and white scales forming the terminal peacock spot give way to long, light-colored hair. This border of delicate hair ceases near the middle of the hinder margin of the wing. The hind wings are slender and armed on the hinder margin with a broad band of delicate light-colored hair. This band becomes narrower toward the tip of the wing. The costal band is scarcely as broad as the wing (Pl. XXXIII, fig. 1).

The moth has a wing expanse of from 7 to 9 mm. and is approximately 5 mm. long when at rest with the wings folded.

NUMBER OF BROODS

This species winters in the pupa stage in a carefully prepared cocoon protected by the folded-over edge of a leaf. In the spring the adults are abundant by the first week in May. By the middle of May the typical tentiform mines begin to appear, and the adults of the first spring brood begin to emerge by the last of May. The life cycle is completed in from four to five weeks. The broods overlap, but beginning with May a fairly well-defined brood can be made out for each month until November. The larvæ of the October brood pupate and live through the winter on fallen leaves. After the moths emerge a considerable period of time elapses before the mines begin to appear. This is undoubtedly due to the fact that the moth, with its well-developed proboscis, feeds for a time before ovipositing.

FOOD PLANTS OF THE LEAF MINER

This leaf miner is primarily a pest of the foliage of the apple. There is where it abounds. However, the small caterpillars have been found developing in considerable numbers in the leaves of the crab-apple (*Malus* sp.), and to a less extent in the leaves of the haw (*Crataegus* spp.), plum (*Prunus* spp.), cherry (*Prunus* spp.), and pear (*Pyrus* spp.). In the case of the last four trees only an occasional mine has been observed. Chambers (2) and others have also reared it from mines in the leaves of the wild cherry (*Prunus* spp.).

CONTROL OF THE LEAF MINER

While this miner may develop in such numbers that from 90 to 95 per cent of all leaves on apple trees may contain from 1 to 10 or 15 mines, it must be said that it is not an especially alarming pest of the orchard (Pl. XXXIII, fig. 14, 15). The pest increases in abundance as the summer and fall advance, so that by September or October much of the foliage may be consumed, but by that time the tree has about completed its growth and matured its crop. However, when conditions are favorable and the pest is abundant, steps should be taken to prevent it from reappearing in injurious numbers the next season.

Since the caterpillar enters the leaf immediately on hatching and remains in the mine until mature and ready to spin its cocoon for pupating, arsenical and contact sprays are of no value. Applications of sprays have given the writer absolutely no results. From the general nature of the pest and its habits, there seems to be no feasible means of controlling it during the growing season. Since it passes the winter as the pupa in cocoons on fallen leaves, it can be effectively controlled by destroying the leaves early in the spring. The most practical method of destroying the pupæ on the leaves is to use a disk for shallow cultivation before the first of March so as to work under the leaves before the moths begin to emerge. Summer cultivation will not help, since the pest is not found on the ground at that time. In a small home orchard the leaves can be raked together and burned or piled and used for leaf mold. If they are not burned, they should be covered with enough soil or stable manure to hasten the decay of the leaves and prevent the moths from emerging in the spring.

PARASITES OF THE TENTIFORM LEAF MINER

It would seem that a caterpillar of this type, which lives protected inside the leaf from the time it hatches from the egg until it is ready to pupate, would be as well protected from natural enemies as from artificial treatment given by man. This does not prove to be the case, however, for the pest is heavily parasitized. It resembles other insect pests which are subject to the attacks of parasites in that under favorable

conditions it increases rapidly and then when the parasites get the upper hand it suddenly disappears. In the summer of 1912 it reached a climax as regards abundance. During the fall the parasites increased in such numbers that but few of the caterpillars escaped to pupate and pass the winter. The check, owing to the beneficial work of the parasites, was complete, for the miner has not attracted attention since 1912.

As the investigation of the miner progressed, it was observed that many of the mines went no farther than the blotch stage, while others arrived at the tentiform stage; but from them no caterpillars emerged. In such mines would be found the dried skin of the caterpillar and the larva or pupa of a parasite. Only casual observations were made on the habits and life cycles of the different species of parasites. One of the common species was found to attack the more mature caterpillars and pupate in a small, oval, white cocoon suspended in the tentiform mine. Others destroyed the younger miners and pupated without producing cocoons in the blotch mines. The grub of one of the parasites was observed to attack the miner just behind the third pair of thoracic legs, paralyzing and eventually destroying it.

The collection of parasites was first submitted to Prof. Crosby, who, from a portion of the collection, identified two species: *Sympiesis nigrifemora* Ash. and *S. tischerae* Ash. Later Mr. Girault examined the collection and identified two new species, *S. meteori* Girault and *Eulophus lineaticoxa* Girault, and one previously recognized species, *S. dolichogaster* Ash. Besides these five species, there were a number of males which were not determined. Brunn (1) reared two species of Sympiesis from the mines of this insect. They were recorded under the manuscript names of *S. minutus* Howard and *S. lithocolletidis* Howard; but the descriptions by Howard were apparently never published, and Ashmead later redescribed the latter species as *S. nigrifemora* Ash.

LITERATURE CITED

(1) Brunn, A. E.
1883. Tineidae infesting apple trees at Ithaca. Cornell Univ. Agr. Exp. Sta. 2d Ann. Rpt. 1882/83, p. 148-162, pl. 5-6.

(2) Chambers, V. T.
1873. Micro-Lepidoptera. *In* Canad. Ent., v. 5, no. 3, p. 41-50.

(3) Dietz, W. G.
1907. The North American species of the genus Ornix Tr. *In* Trans. Amer. Ent. Soc., v. 33, no. 2/3, p. 287-297, pl. 4.

(4) Forbes, S. A.
1889. The apple Ornix. *In* 15th Ann. Rpt. State Ent. Ill. [1884/86], p. 51-57.

(5) Jarvis, C. D.
1906. The apple leaf-miner. A new pest of the apple. Conn. Storrs Agr. Exp. Sta. Bul. 45, p. 37-55.

(6) Lowe, V. H.
1900. Two apple leaf miners. *In* N. Y. Agr. Exp. Sta. Bul. 180, p. 131-135, pl. 6-7.

(7) Packard, A. S.
1869. Guide to the study of insects. 702 p., illus., 11 pl. Salem.

PLATE XXXIII

Ornix geminatella Pack.:

Fig. 1.—Moth expanded. × 10.

Fig. 2.—Moth at rest on leaf. × 2½.

Fig. 3.—Egg on lower surface of leaf; also tunnel made by miner on leaving the egg. × 80.

Fig. 4.—Dorsal view of first larval stage; below, side view of head and thorax. × 18.

Fig. 5.—Dorsal view of second larval stage. × 18.

Fig. 6.—Side view of second larval stage. × 18.

Fig. 7.—Dorsal view of third larval stage, showing edge of thoracic legs. × 18.

Fig. 8.—Dorsal view of fourth larval stage. × 18.

Fig. 9.—Side view of fourth larval stage. × 18.

Fig. 10.—Ventral view of pupa. × 18.

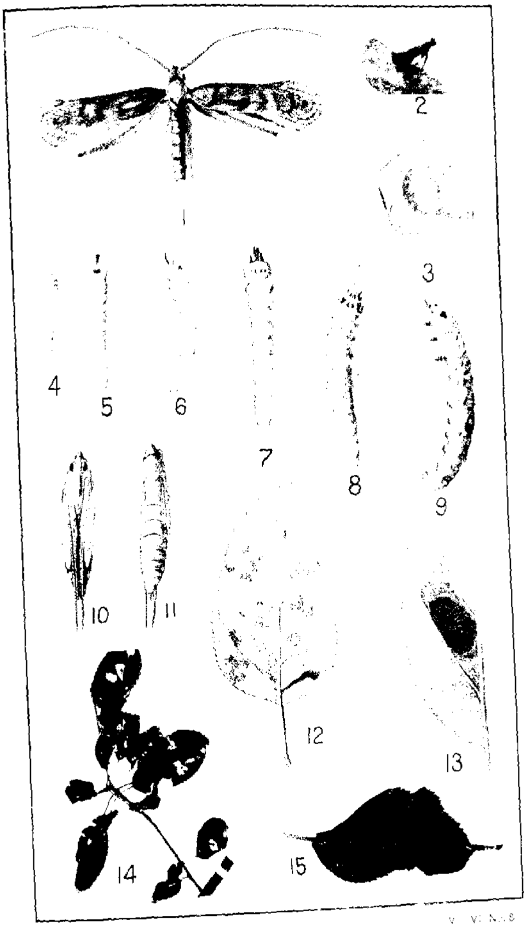
Fig. 11.—Dorsal view of same. × 18.

Fig. 12.—Lower surface of leaf with numerous partly developed mines; also two cocoons, one exposed. The cocoon is usually on the upper surface of the leaf. × 1.

Fig. 13.—Portion of leaf showing a mine in process of development. The serpentine mine was completed on June 24, the small darkly shaded area of the blotch mine June 25, the second area on June 27, the third area on June 29, and on June 30 the blotch was completed and then transformed to the tentiform mine. × 2. Egg more enlarged.

Fig. 14.—A small twig showing leaves badly curled and injured by numerous mines. × ¾.

Fig. 15.—Leaf much distorted with 10 mines almost completed; also one cocoon appears at the tip of the leaf. Natural size.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
SUBSCRIPTION PRICE, $3.00 PER YEAR
▽